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Nuclear Theory Group

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Research Activities

(I) A FEW BODY PROBLEMS

a. Tensor interaction in nucleon-nucleon system[1] (T.Sasakawa and S. Ishikawa)

For Some time, it has been known that a potential which yields a small D-state probability of the deuteron produces a favorably large binding energy of the triton. To account for this statement, we have demonstrated that if the tensor component of the N-N interaction is small, the central potential acting to the S-state should be more attractive compared with a potential with usual tensor force, so that the correct value of the deuteron binding energy may be obtained. As a result, the triton binding energy becomes large. However, if the tensor component is small, the S-D mixing parameter $\bar{\epsilon}_1$ is too small over a large energy range to account for the experimental values. Therefore, we concluded that the legitimacy of a N-N potential should be judged from the behavior of $\bar{\varepsilon}_1$ and not only from the calculated triton binding energy.

b. Test of charge symmetry breaking (T. Sasakawa and S. Ishikawa)

To study the amount of charge symmetry breaking in the N-N interaction is a fundamental issue in nuclear physics, related to the subnuclear structure of a nucleon and/or the interaction between two nucleons. We have orgnized a workshop on this topic one day before PANIC (April 20-24, 1987) in Kyoto. The work shop was held at the Kyodai-kaikan. The participants were specialists of this topic: Tony Thomas, Alex Gersten, Gordon Greeniaus, Jauni Nisakanen, S.Ishikawa and T.Sasakawa. The Most part of discussions were devoted to the n-p polarization experiment and theory in relation to the charge symmetry breaking. Also the importance of $\bar{\varepsilon}_1$ was discussed. A full report of this workshop will appear in Few-Body Systems in 1988.

c. Quark and the triton (T. Sasakawa, S. Ishikawa, T. Inaba)

J. Weber et al. constructed a nucleon-nucleon potential which incorporates a short range part that is traced back to the P-matrix theory of the quark structure of a nucleon. We call this potential the Virginia potential. This potential reproduces the low energy behavior of the N-N scattering and the deuteron properties very well. Using this potential, we have calculated the triton binding energy. We obtained the following conclusions. (i) The triton is a very sensitive system to check the short range behavior of the N-N potential than the deuteron. (ii) The energy dependence of the short range part is very important to this potential. (iii) The 34-channel calculation yields 8.04 MeV for the triton binding energy, which is 0.4 MeV 0.5 MeV larger than the realistic potential model results. (iv) Since this value of 8.04 MeV is less than the experimental value of the tritron binding energy, we need a three-body force.

d. Photo-disintegration of triton (T. Sasakawa, S. Ishikawa and T. Saito)

Using our very accurate triton wave function, we calculated the photodisintegration of the triton. For energies lower than the three body breakup threshold, we used the exact wave function of the n-d system. Above it, we did not take account of the final state interaction. We concluded the following. (i) The E1 transition mainly contributes to the process. The M1 transition is less than 15%. If we take the final state interactions into account, the contribution from the M1 transition will be much less. The contribution from the meson exchange current is the order of several %. (ii) Increase in the number of the triton channel makes the binding energy increase. This results in the decrease of the cross section. (iii) In general, the cross section scales with the calculated binding energy of the used potential. (iv) The present calculation yields smaller cross section than the experimental result. Therefore, the effect of the final state interaction must be very important.

e. Caluculation of ^{3}He with full Coulomb interactions (T. Sasakawa, S. Ishikawa and Y. Wu)

Using the Sasakawa-Sawada equation, we are calculating the binding energy and the wave function of ^{3}He taking account of full Coulomb interactions. Once we have calculated it for 3 channels (T. Sasakawa, H. Okuno and T. Sawada, Phys. Rev. C 23 (1981), 905). This time, we are calculating it for 34 Channels. We are using the method of continued fractions to solve the S-S equation. The calculation takes 190.62 seconds for SX1 super computer. We obtained the following values for the binding energy of ^{3}He (^{3}H): Argonne potential 7.023 (7.692) MeV and Paris potential 6.985 (7.648) MeV. Therefore, the Coulomb energy differences are 0.669 MeV for the Argonne potential and 0.663 MeV for the Paris potential. The calculation of ^{3}He is thus performed for the first time in the world, taking account of full Coulomb interactions.

f. Effects of the rho meson exchange three-nucleon potential and y-scaling.

(T. Sasakawa, S. Ishikawa and T. Takahashi)

The effect of the $\pi-\rho$ and $\rho-\rho$ exchange three-body force is being tested for the triton binding energy and for the y-scaling in the inclusive quasielastic electron scattering. It turns out that the non-static effect of the propagating Δ gives the repulsive effect for the processes $\pi\Delta\pi$ and $\pi\Delta\rho$. The contributions from these processes are not large.

g. Study of Two-Nucleon System in Relativistic One-Boson-Exchange Model (A. Fukunaga)

Some relativistic two-body equations were solved for the two-nucleon systems (scattering states[2] and deuteron) in the one-boson-exchange model. The momentum distribution and the y-scaling function of deuteron were calculated and the effects of the high momentum component and the negative energy state were investigated. Moreover, the differential cross section of deuteron electro-disintegration reaction was also calculated using the relativistic deuteron wave function.

h. International Conferences[3,4] (T. Sasakawa)

Reports on the Eleventh International IUPAP Conference on Few Body

Systems in particle and Nuclear physics, 24-30 August, 1986 held at Tokyo and Sendai were given at PANIC and in BUTSURI.

(II) HEAVY ION COLLISIONS

a. Dynamics of Heavy Ion Fusion Reactions
(N. Takigawa and A. Iwamoto(JAERI))

We extended our studies in previous years on the effects of intrinsic degrees of freedom on the fusion cross section in medium-weight heavy ion collisions. Using the two centre shell model, we clarified that the anomalously large enhancement of the sub-barrier fusion cross section in ^{74}Ge + ^{74}Ge scattering is caused by the cooperative effects of the sheel correction energy and the deformation energy around the fusion barrier.

b. Decay of a Hot Compound Nucleus (N. Takigawa and M. Abe)

We have investigated the effects of the coupling to low lying nuclear vibrations and those of the primary excitation of the residual nucleus on the particle decay from a hot compound nucleus. We found that they strongly affect the energy spectrum at low energies. The peak of the spectrum is shifted to a lower energy compared with that of the conventional statistical model. We showed that the thermal fluctuation of nuclear surface amplifies the dynamical effects.

c. Production of Super Heavy Elements by Neutron Rich Beams
(N. Takigawa, M. Abe and T. Shinozuka(Cyclotron-RI Center))

We have investigated the advantages of using neutron rich beams in creating super heavy elements. We found that one can reduce the so called extra push energy by using neutron rich beams. Neutron rich beams have an advantage also in increasing the survival probability of the fusion synthesized compound nucleus.

(III) INTERMEDIATE ENERGY

a. Isoscalar Giant Monopole states of Finite Nuclei in the σ-ω model
(T. Maruyama and T. Suzuki(Kyoto Univ.))

Isoscalar giant monopole states of finite nuclei are studied in the σ-ω model using a relativistic constrained Hartree method. The incompressibility of heavy nuclei is about 330 Mev in the σ-ω model. This value yields excitation energies of monopole states to be $120A^{-1/3}$ MeV, which is by 1.5 times higher than the experimental value, but better than that of nuclear matter.

(IV) STATISTICAL APPROACHES TO HADRONIC / NUCLEAR REACTIONS

a. Semi-inclusive Rapidity Distributions From Entropy Maximization
(F. Takagi and T. Tsukamoto)

We propose a very simple analytic formula for single particle semi-inclusive rapidity distributions of hadrons produced in a multiple production process with n final state hadrons and no leading particles: $\sigma_n^{-1} d\sigma_n/dy = \rho_n(y) = A_n \exp(-B_n \cosh y)$. This form is obtaind by maximizing information theoretical entropy defined in terms of $\rho_n(y)$ subject to the normalization and the energy-momentum conservation. It reproduces with high accuracy the result which was obtained from a longitudinal phase space model, in particular, when the multiplicity n is large.

b. Surprisal Analysis of the $^{63,65}Cu(\gamma,p_0)$ Reactions
(T. Tsukamoto, Y. Kawazoe, H. Miyase and H. Tsubota)

Surprisal analysis is applied to photoreaction. The statistical model of Hauser-Feshbach is extended to analyze the $^{63,65}Cu(\gamma, p_0)$ reactions. A unified understanding of the measured cross sections in the giant resonance energy region, which has yet to be achieved, is attempted.

C. Linear Surprisal and Stochastic Process.II (T. Tsukamoto, T. Honda, H. Matsuzaki and C. Ishii(Tohoku College of Pharmacy))

Among birth and death processes with discrete spaces only the simple birth, death and immigration process (SBDI) preserves the linearity of surprisal; that is, if once the surprisal occurs to be a linear function of the observables under consideration it will remain so forever. Among one-dimensional diffusion processes we show that "linear surprisal" is preserved only for those obtained as the limiting process of an SBDI. The time development of the variance, however, is essentially different between an SBDI and its diffusion process limit; the variance for the latter never decreases unlike the one for the former. Some examples for violation of the linear-surprisal preservation condition are also discussed.

d. $^{89}Y(\gamma, p_0)$cross section deduced from the $^{89}Y(e, p_0)$reaction
(H. Miyase and H. Tsubota, Y. Kawazoe, T. Tsukamoto)

Angular distribution of the $^{89}Y(e,Po)$ reaction has been measured in the giant resonance energy region at 12 laboratory angles ranging from 30° to 140°. The obtained differential cross sections have been decomposed into E1 and E2 components using a resonance model. The E1 and E2 components of the $^{89}Y(\gamma, p_0)$ cross section were estimated to exhaust 2.9% and 1.7% of the E1 and E2 sums, respectively. The derived excitation functions for E1 and E2 are well explained by a direct-semidirect model. The result confirms the isovector giant quadrupole excitation in ^{89}Y.

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Phys. Rev. c 36 (1987)

Doctor Thesis (March 1987)

1) Quasi potential equation approach in two nucleon system,
Atsusi Fukunaga
2) Relativistic approach in quasi elatic electron scattering and giant resonance, Tomoyuki Maruyama

Master Thesis (March 1987)

1) Effect of quark degrees of freedom on three-nucleon system,
Toshio Inaba
2) Photodisintegration of triton, Toshiyuki Saito